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TNO: Netherlands Organization for Applied Scientific Research

- Founded in 1932 by act of parliament (*TNO law*)
- € 640 turn-over (1/3 direct government funding)
- 4,200 staff

- *Applied* R&D organization
  - technology development
  - contract R&D
  - non-routine consulting
  - special tasks (*Geological Survey of The Netherlands*)

- Independent, transparent, not-for-profit
- Focus on fundamental understanding & knowledge transfer
- *Comparable to IFP, SINTEF, CSIRO, KISR*
TNO organization

MARKETS

- Healthy Living
- Transport & Mobility
- Industrial Innovation
- Energy

EXPERTISE

- Defence, Safety & Security
- Information Society
- Built Environment
- Technical Sciences
- Behavioural & Societal sciences
- Earth, Environmental & Life Sciences
Our position in innovation

- Demand or Opportunity
- Fundamental Research
- Research Ideas
- Feasibility & Concept design
- Proof of principle
- Functional Model
- Prototype Pilot
- Production preparation
- Trials Tests
- Production Sales

Research
R&D
Product development

- Technical aspects
- Regulatory aspects
- Commercial aspects

Universities
TNO and/or company R&D
Company and/or manufacturer
Status of CCS in Europe & Netherlands
Within Europe CCS provides 24 per cent of the solution in power AND Industrial sector (source IEA).

- **CCS power generation**: 12%
- **CCS industry and transformation**: 12%

**Other categories**:
- Building efficiency: 18%
- Second generation biofuels: 6%
- FCV: 2%
- PHEV and EV: 4%
- Transportation efficiency: 11%
- Industry fuel switching: 2%
- Industrial efficiency and recycling: 4%
- Other power generation: 11%
- Wind: 3%
- Solar: 1%
- Other building reductions: 7%
- Nuclear: 7%
Overview large scale EU CCS demonstration projects

CCS Project Pipeline

EEPR

6

NER300 (1st Call)

13

UK 7

NL 1

DE 1

PL 1

FR 1

IT 1

RO 1
Netherlands; strategically located between CO2 emissions (peaks) and storage locations in North Sea
Why CCS and the Netherlands:

- Availability (clustered) large CO₂ point sources
- Large storage capacity; > 3 Gton
- Relatively short transport distances
- Extensive knowledge of oil & gas and CCS
- CATO R&D program since 2004
- Serious business interests and commitment of relevant parties
- Substantial government funding
- 2 large scale demo’s
Rotterdam: 4th largest port in the world
Port of Rotterdam yesterday...
Today...
... and in 2030:

Maasvlakte 2: 1000 hectares new land
CO₂ sources
1. Shell (since 2005)
2. Abengoa (since 2011)
3. ROAD (2016 / 2017)

CO₂ logistics
- OCAP
- R3CP: common carrier collection pipeline
- Offshore pipeline to CO₂ Terminal

CO₂ destinations
- greenhouses for enhanced crop growing
- Taqa P18 Gasfield
- EOR North Sea

Off shore gas reservoirs
Westland greenhouse area
Other greenhouse areas

ROTTERDAM CO₂ Network:
4 emitters, CO₂ storage & utilisation
ROAD CCS DEMO (250 MW PC); FEED study P18 storage location executed by TNO
General Overview
CATO in a glance

- Applied and scientific research
- Complete CCS Chain
- Demand driven & flexible program
- 86 M€ (50% government)
- 200 researchers & 45 PHD students
- Coordination: TNO
- 2004-2013
- Partners from industry, SME, university, NGO
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Research Locations

Original Locations
### SP-1: Capture

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<td>- Fundamental: Develop second generation capture technology</td>
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## Overview and Highlights

### 1.1 'post'

- WP 1.1A1 User Requirement Specification
- WP 1.1A2 DEMO Preliminary Design
- WP 1.1A3 Solvents
- WP 1.1A4 Absorber
- WP 1.1A5 STRIPPER
- WP 1.1A6 Process development
- WP 1.1A7 Environmental Aspects
- WP 1.1A9 CO2 capture at Municipal Solid Waste Combustion (MSWC) plants
- WP 1.1F1 Phase Change Solvents
- WP 1.1F3 Thermodynamic Models
- WP 1.1F5 Adsorptive Systems
- WP 1.1F6 Hybrid system for gas fired power plants
- WP 1.1F7 Multiple Phases Absorption Liquids
- WP 1.1F8 Multiple Phases Pilot

### 1.2 'pre'

- WP 1.2A1 CO2-CATCHUP: Plant operation and optimization
- WP 1.2A2 Water gas shift catalysis
- WP 1.2A3 CO2-CATCHUP: CO2 absorption section
- WP 1.2A4 Sorption-Enhanced Water Gas Shift (SEWGS)
- WP 1.2A5 Industrial CCS at Tata Steel
- WP 1.2F1 Hydrogen Membrane Technologies
- WP 1.2F2 Nano-structured sorbents for CO2 capture
- WP 1.2F3 Novel materials for H2 - CO2 separation
- WP 1.2F6 High pressure and temperature selective solvents

### 1.3 'oxy'

- WP 1.3F2 Chemical Looping Combustion
- WP 1.3F3 Oxy combustion of solid fuels

### 1.4 Techno-economic evaluation & Benchmarking

- WP 1.4 Techno-economic evaluation & Benchmarking

### 1.5 CCS in Northern Netherlands (RWE)

- WP 1.5 CCS in Northern Netherlands (RWE)

### 1.6 Toxicology and Ecotoxicology of Carbon Dioxide and CCS by-products

- WP 1.6 Toxicology and Ecotoxicology of Carbon Dioxide and CCS by-products

### 1.7 CO2 Re-use

- WP 1.7 CO2 Re-use

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**Work packages:**

CATO2

SP1 Capture

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Overview

And

Highlights
Post Combustion Capture

CATO Pilot (2008) at E.ON Maasvlakte

Flue gas details:
- 1250 m$^3$/hr flue gas, 250 kg/hr CO$_2$ captured
- Flue gas gas from pulverized coal power plant
- 90% of CO$_2$ captured from flue gas side-stream
Pre-Combustion Capture

Pd/alloy membranes

Buggenum pilot plant

Sorption Enhanced Water Gas Shift
WP1.3 Oxyfuel

• Fundamental research
  – Fixed bed chemical looping combustion (PhD)
  – Oxy combustion of solid fuels
SP-2 Overview

SP-2: CO2 transport and chain integration

- Technical aspects of CO2 transport infrastructure
- Techno-economic chain analysis
- International CCS policy
- Chain integration and CCS implementation plan
- Technical assessment of the ROAD CCS chain in non-steady conditions
CCS Roadmap for the Netherlands
### SP-3: Underground storage, monitoring, verification

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<td>Well integrity</td>
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<td>Additional benefits of CO2 injection (EOR &amp; temporal buffering)</td>
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<td>Shallow (sub-) surface monitoring</td>
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<td>Site-specific monitoring</td>
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GDF-Suez K-12B

Offshore Enhanced Gas Recovery, CO2 gas treatment

1st test: K12-B8 - Injector
2nd test: K12-B5 - Producer
2nd test: K12-B1 - Producer
2nd test: K12-B6 - Injector
ROAD Storage location; The P18-4 gas field
### SP-4: Regulation and safety

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SP-5 Overview

Barendrecht gaat in verzet tegen CO2-opslag

ANP op 18 november '09, bijgewerkt 19 november '09, 11:46

Barendrecht protesteert tegen CO2-opslag (RTV Rijnmond)

BARENDRECHT - De gemeente Barendrecht legt zich er niet bij neer dat in de gemeente een proef komt met de opslag van het broeikasgas CO2.

- Barendrecht krijgt CO2-opslag

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SP-5: Public perception

Local communication near CCS

Framing effects in CCS communication

Trends in public opinion about CCS

Resistance of valid beliefs about CCS against low quality information
CO2 Capture, Transport and Storage in The Netherlands

Online Workspace: share documents & find templates

For each SP and WP there is a folder. And each WP folder has three subfolders. This section is only activated for work documents, minutes and other 100% CATO-2 files such as CATO-2 power point templates, election forms etc. Below. Deliverables will be published in the Public Sharing part. Please note that uploading a new version of a document is very simple, just click on the older version. The system saves both old and newer documents.

Browse documents from CATO-2 members

Categories:
- Presentations
- SP1 Capture
- SP2 CO2 transport and chain integration
- SP3 Storage, monitoring and verification
- SP4 Regulation and safety
- SP5 Public perception
- SP6 Communication
- Consortium Bodies
- Programmes office
- Themes
- General (2)

Public Website: www.co2-cato.nl